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ABSTRACT

This activity is designed to teach how tectonic plates move, what some consequences of this motion are, and how magnetic anomalies document the motion at spreading centers do. The activity provides learning objectives, a list of needed materials, key vocabulary words, background information, day-to-day procedures, internet connections, career ideas, integrated subject areas, evaluation tips, extension ideas, and National Science Education Standards connections. (KHR)

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ED 477 325

The Biggest Plates on Earth

Submarine Ring of File – Grades 5-6

Plate Tectonics

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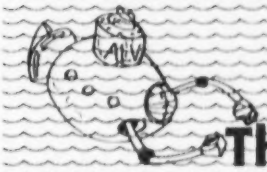

The Biggest Plates on Earth

Focus
Plate tectonics

Grade Level
5-6

Focus Question
How do tectonic plates move, what are some consequences of this motion, and how do magnetic anomalies document the motion at spreading centers?

Learning Objectives
Students will be able to describe the motion of tectonic plates, and differentiate between three typical boundary types that occur between tectonic plates.

Students will be able to infer what type of boundary exists between two tectonic plates, given information on earthquakes and volcanism in the vicinity of the boundary.

Students will understand how magnetic anomalies provide a record of geologic history around spreading centers.

Students will be able to infer the direction of motion between two tectonic plates given information on magnetic anomalies surrounding the spreading ridge between the plates.

Students will be able to describe plate boundaries and tectonic activity in the vicinity of the Juan de Fuca plate.

Materials
- ❒ Copies of "Pacific Basin Tectonic Plates," one copy per student or student group
- ❒ Copies of "Magnetic Anomalies on the Juan de Fuca Plate," one copy per student or student group

Audio/Visual Materials
- ❒ (Optional) Overhead transparency of cross-section illustrating the main types of plate boundaries (download from U.S. Geological Survey web site: http://pubs.usgs.gov/publications/text/Vigil.html)
- ❒ (Optional) Overhead transparency of map illustrating the Ring of Fire (from U.S. Geological Survey web site: http://pubs.usgs.gov/publications/text/fire.html)
- ❒ (Optional) Overhead projector

Teaching Time
Two or three 45-minute class periods

Seating Arrangement
Classroom or groups of two to four students

Maximum Number of Students
30

Key Words
Basalt
Ring of Fire
Asthenosphere
Lithosphere
Magma
Fault
Transform boundary

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Convergent boundary
Divergent boundary
Subduction
Magnetic anomaly
Tectonic plate
Spreading center

Background

The Ring of Fire is an arc of active volcanoes and earthquake sites that partially encircles the Pacific Ocean Basin. The location of the Ring of Fire coincides with the location of oceanic trenches and volcanic island arcs, and was one of the early clues that led to the theories of continental drift and plate tectonics. In 1940, Hugo Benioff, an American seismologist (a scientist who studies earthquakes), charted the location of deep earthquakes in the Pacific Ocean. He found that earthquake sites are distributed in an arc that spanned both sides of the ocean. Five years earlier, Japanese seismologist Kiyoo Wadati had noticed a similar pattern, and suspected that it was connected in some way to the idea of continental drift. He was right.

Today we know that the outer shell of the Earth (called the lithosphere) consists of about a dozen large plates of rock (called tectonic plates) that move several centimeters per year relative to each other. These plates consist of a crust about 5 km thick, and the upper 60 - 75 km of the Earth's mantle. The plates that make up the lithosphere move on a hot flowing mantle layer called the asthenosphere, which is several hundred kilometers thick. Heat within the asthenosphere creates convection currents (similar to the currents that can be seen if food coloring is added to a heated container of water). These convection currents cause the tectonic plates to move. Plates may slide horizontally past each other at transform plate boundaries. The motion of the plates rubbing against each other sets up huge stresses that can cause portions of the rock to break, resulting in earthquakes. Places where these breaks occur are called faults. A well-known example of a transform plate boundary is the San Andreas Fault in California.

Another type of plate boundary is formed where tectonic plates are moving apart. At these divergent plate boundaries, magma (molten rock) rises from deep within the Earth and erupts to form new crust on the lithosphere. Most divergent plates boundaries are underwater (Iceland is an exception), and form submarine mountain ranges called oceanic spreading ridges. While the process is volcanic, volcanoes and earthquakes along oceanic spreading ridges are not as violent as they are at convergent plate boundaries where tectonic plates are being pushed together. Usually one of the converging plates moves beneath the other (a process called subduction). Deep trenches are often formed where tectonic plates are being subducted, and earthquakes are common. As the sinking plate moves deeper into the mantle, fluids are released from the rock causing the overlying mantle to partially melt. The new magma rises and may erupt to form volcanoes, often forming arcs of islands along the convergent boundary.

On the Pacific Ocean tectonic plate, the production and recycling of lithospheric crust has been likened to a huge conveyor belt system in

which new crust is formed at the oceanic spreading ridges off the western coasts of North and South America, and older curst is returned to the lower mantle at the convergent plate boundaries along the underwater volcanoes and island arcs of the western Pacific. The 2002 Submarine Ring of Fire Expedition is investigating the formation of new ocean crust at the edge of the Juan de Fuca tectonic plate off the coast of western North America. This is a comparatively small tectonic plate, and as a result has a divergent boundary (with the Pacific plate) as well as a convergent boundary (with the North American plate) relatively close together. The eruption of Mt. St. Helen in 1980 was a result of the subduction of the Juan de Fuca plate beneath the North American plate. The divergent boundary is an active spreading center that is organized along three ridges: Gorda Ridge, Juan de Fuca Ridge, and Explorer Ridge. While Gorda and Juan de Fuca Ridges have been intensively studied, Explorer Ridge is virtually unexplored and is the focus of the 2002 Submarine Ring of Fire Expedition.

One of the first tasks for the expedition is to prepare maps of the seafloor around Explorer Ridge to aid in identifying the most promising sites for investigation. In addition to topographic maps prepared with a multibeam sonar system (see http://oceanexplorer.noaa.gov/explorations/02alaska/background/edu/media/mapping7_8.pdf, scientists will also make detailed measurements of magnetic fields around the Ridge to reveal features that will not be detected by the sonar system. Measurements of magnetic variations on the ocean floor have provided critical evidence for theories of continental drift and plate tectonics. When magma erupts along oceanic spreading ridges, it contains high concentrations of various minerals, including magnetic minerals, such as iron and magnetite that align with the Earth's magnetic field like a compass needle. When magma cools to form solid rock (basalt), particles of magnetite become immobilized, and provide a record of the position of the Earth's magnetic field when the magma erupted.

The Earth's magnetic field periodically reverses (so that compass needles point to the south instead of the north) at irregular intervals that average around 400,000 years. The alignment of magnetic particles in crust that was formed during periods of reversal is opposite to that of particles produced when the Earth's magnetic field is oriented similarly to the present. Scientists have found that the intensity of the Earth's magnetic field varies around spreading centers; in some locations it is stronger than normal, in other locations it is weaker. These variations are called magnetic anomalies, and are the result of magnetic minerals in the basalt rocks. If the minerals were "locked" into the rocks when the Earth's magnetic field was similar to its present magnetic field, then the magnetism of the minerals is added to the Earth's magnetic field, so the total magnetic intensity is greater than normal; this is called a "positive magnetic anomaly." On the other hand, if the minerals were "locked" into the rocks when the Earth's magnetic field was opposite to its present magnetic field, then the magnetism of the minerals opposes the Earth's magnetic field, so the total magnetic intensity is less than normal; this is called a "negative magnetic anomaly."

When positive and negative magnetic anomalies are measured on either side of an oceanic spreading center, they form a zebra stripe-like pattern with the stripes running parallel with the ridge of the spreading center. Scientists have reconstructed the history of magnetic reversals for the past 4 million years using a dating technique based on isotopes of potassium and argon (see http://oceanexplorer.noaa.gov/explorations/02alaska/background/edu/media/mapping7_8.pdf. Using this information, they have been able to calculate the age of the magnetic anomaly "zebra stripes," and the rate at which tectonic plates are moving away from their spreading centers.

This lesson is divided into two parts. In the first part, students will infer whether plate boundaries associated with the Pacific Ring of Fire are divergent, convergent, or transform based on information about earthquakes and volcanic activity in the vicinity of the boundaries. In the second part, students will use magnetic anomaly data to draw inferences about the spreading center system on the divergent boundary of the Juan de Fuca plate.

Learning Procedure

1. Explain the concept of plate tectonics and continental drift. Be sure students understand the idea of convergent, divergent, and transform boundaries, as well as the overall type of earthquake and volcanic activity associated with each type of boundary (strong earthquakes and explosive volcanoes at convergent boundaries; slow-flowing volcanoes, weaker earthquakes at divergent boundaries; strong earthquakes, rare volcanoes at transform boundaries). Discuss energy transfers involved in plate motions, earthquakes, and volcanoes. You may want to use materials from "This Dynamic Earth" and/or "This Dynamic Planet" (see Resources section), but do not give away the answers to the predictive exercise on the Pacific Basin Tectonic Plates.

2. Distribute copies of "Pacific Basin Tectonic Plates" to each student or student group. Have each group decide what type of boundary exists at the indicated sites. Tabulate each group's results, and lead a discussion of the reasoning behind their conclusions. If you want to use this exercise for evaluation, collect the worksheets before discussion.

3. Explain the idea of magnetic anomalies, and draw the students' attention to the area around the Juan de Fuca plate. Do not give too much detail on the plate at this point; just talk about where it is in relation to the United States and Canada. Be sure the students realize that the small size of the plate brings convergent and divergent boundaries relatively close together. The fact that subduction of the plate at its convergent boundary with the North American plate caused the Mount St. Helen's eruption should provide an opportunity to spark students' interest.

4. Distribute copies of "Magnetic Anomalies on the Juan de Fuca Plate" to each student or student group. Have each group discuss the handout, and write their con-

clusions on the worksheet. Lead a discussion of the reasoning behind these conclusions. Students should infer that the magnetic anomalies occur on either side of a divergent plate boundary (between the Juan de Fuca and Pacific plates), and that the youngest rocks are closest to the spreading center at the boundary of the two plates. Students should also realize that the interruptions in the anomaly "stripes" represent separate spreading centers resulting from faults along the boundary between the plates. At this point, name the three ridges where these spreading centers are located (Gorda Ridge to the south, Juan de Fuca Ridge in the middle, and Explorer Ridge to the north), and introduce Explorer Ridge as the site of the 2002 Ocean Exploration Ring of Fire Expedition.

The BRIDGE Connection

www.vims.edu/bridge/geology.html

The "Me" Connection

Have students write a first-hand account of a visit to a plate boundary, describing where the boundary occurs and what conditions are found there.

Connections to Other Subjects

English/Language Arts, Geography

Evaluation

Both worksheets may be used to evaluate students' understanding of the concepts presented. Alternatively or additionally, students may be asked to define key words, and/or identify the type of boundaries and expected conditions at the junctions of other tectonic plates.

Extensions

Have students visit http://oceanexplorer.noaa.gov to keep up to date with the latest Ring of Fire Expedition discoveries.

Resources

http://oceanexplorer.noaa.gov – Follow the Ring of Fire Expedition daily as documentaries and discoveries are posted each day for your classroom use. A wealth of information can also be found at this site.

http://pubs.usgs.gov/publications/text/dynamic.html#anchor19309449 – On-line version of "This Dynamic Earth," a thorough publication of the U.S. Geological Survey on plate tectonics written for a non-technical audience

http://pubs.usgs.gov/pdf/planet.html – "This Dynamic Planet," map and explanatory text showing Earth's physiographic features, plate movements, and locations of volcanoes, earthquakes, and impact craters

National Science Education Standards

Content Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard B: Physical Science

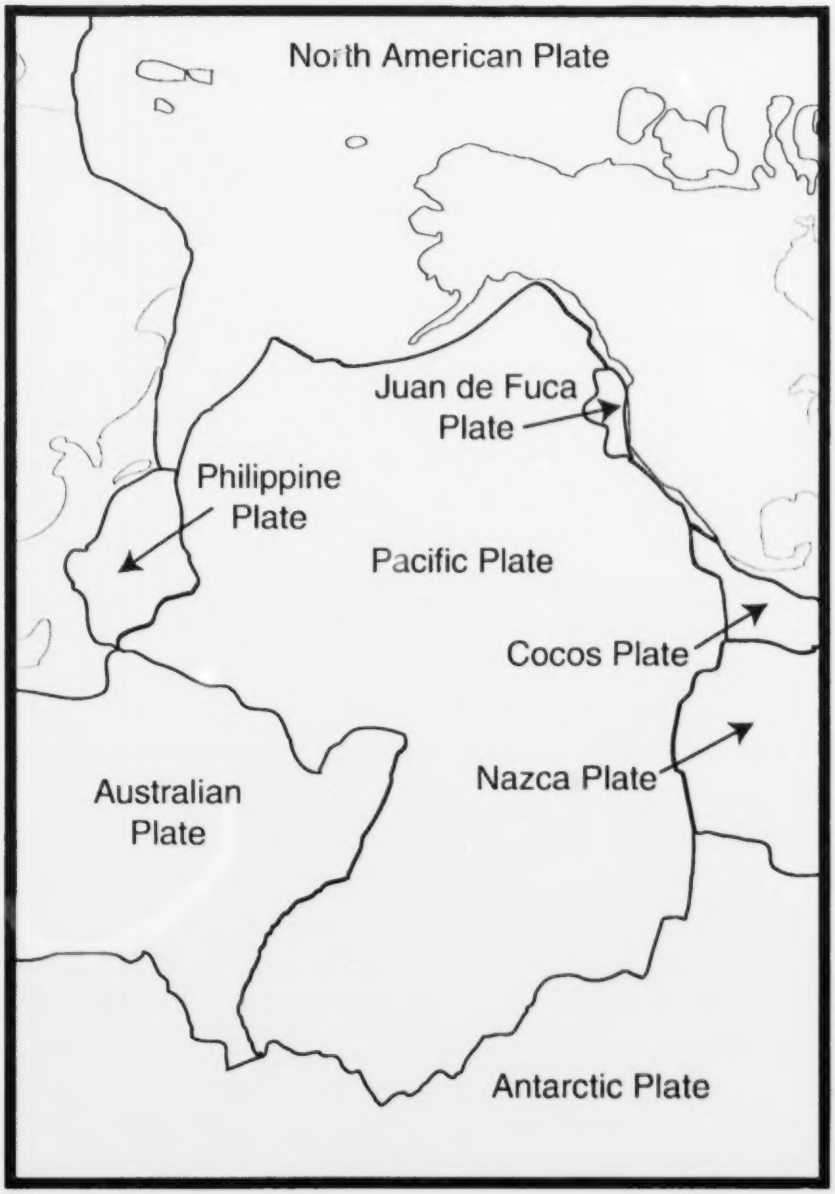
- Transfer of energy

Content Standard D: Earth and Space Science

- Structure of the Earth system

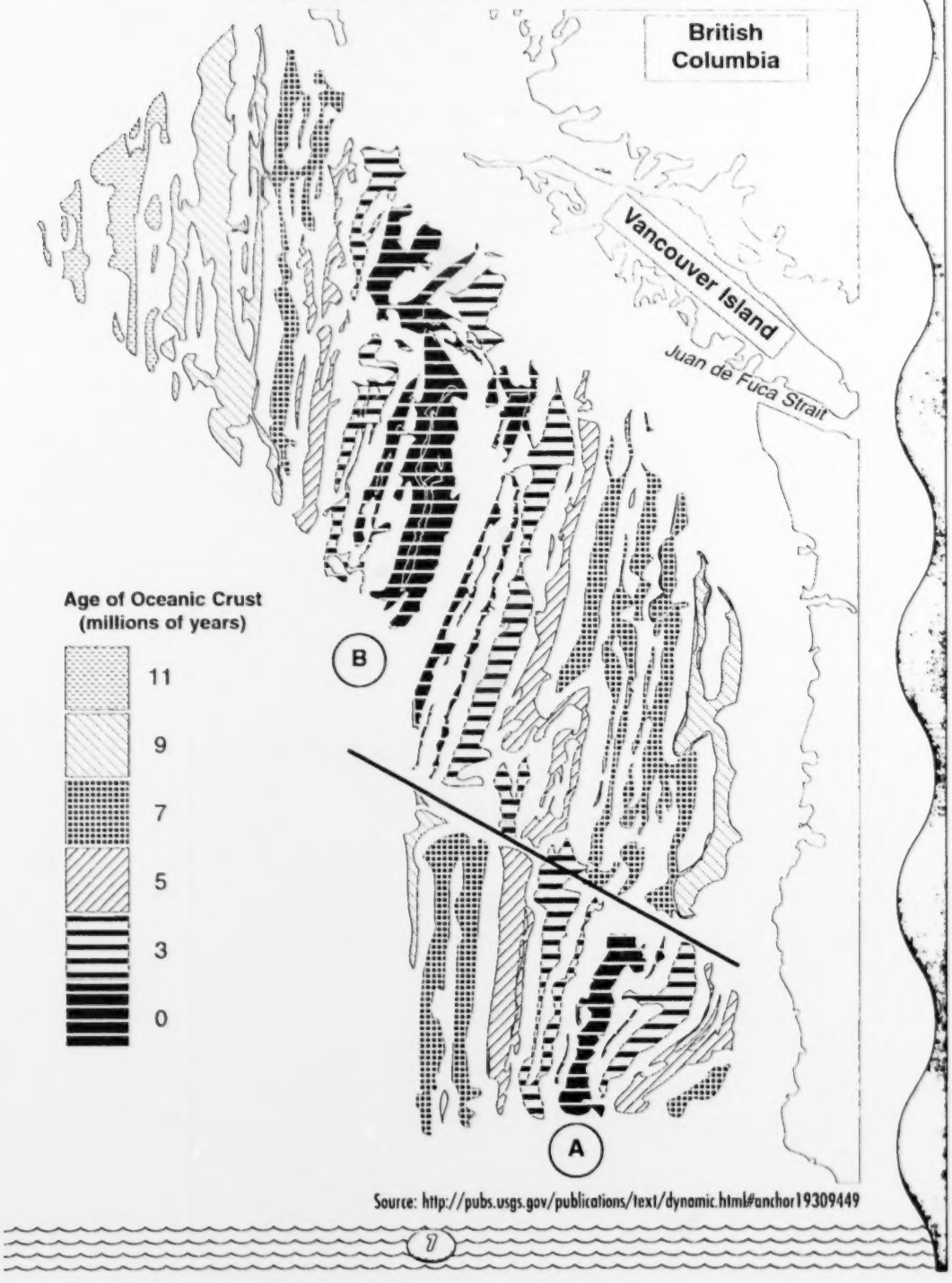
Activity developed by Mel Goodwin, PhD, The Harmony Project, Charleston, SC

Student Data Sheet
Tectonic Plates Bordering the Pacific Basin



Student Data Sheet

Magnetic Anomolies on the Juan de Fuca Plate



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